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Using Serious Games in Data Communications and Networking Management Course

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Abstract

Data Communications and Networking Management is one important course taught in business schools. To prepare themselves for future career, students need to acquire the data communications skills and the higher-order cognitive skills (HOCS) from this course so that they relate the relevance of the theory to practical problems. Prior literature shows that serious games offer an ability to trigger enjoyment in learning this difficult subject. Therefore, in this study, we empirically examined the effects of serious game feature on students' learning experience, focusing particularly on concentration and enjoyment, as well as measuring the perceived improvement in their HOCS. The results revealed that features of serious games have positive effects on students' concentration and enjoyment, and such learning experience did indeed significantly improve their perceived HOCS. The results encourage faculty members to adopt serious games to teach difficult subjects in the field of management information systems.

Keywords: applications in subject area; computer-mediated communication; serious games; multimedia/hypermedia systems; interactive learning environments.

INTRODUCTION

Data Communications and Networking Management is one of the most important courses taught in undergraduate Management Information System (MIS) programs (Gill and Hu, 1999; Kung, Yang and Zhang, 2006). This course provides MIS students with “an in-deep knowledge of data communications requirements including networking and data communications and networking technologies, hardware, and software” in the types of organizations they are likely to be working in after graduation (Ehie, 2002, p.155). These skills are deemed to be important for a successful career in IT (Bullen, Abraham, Gallagher, Simon and Zwieg, 2009). Organizations not only need their employees to master the technical skills involved, but also to possess higher-order cognitive skills such as critical thinking and analysis, decision-making and problem-solving (Beard, Schwieger and Surendran, 2008; Downey, McMurtrey and Zeltmann, 2008).

The higher-order cognitive skills (HOCS) enhance students' abilities to identify, integrate, evaluate and connect concepts within a task in order to make better decisions and solve practical problems (Bradley, Sankar, Clayton, Mbarika and Raju, 2007; Zoller, 2002). HOCS enable students to apply the knowledge that they learn in class to solve practical problems (Bagarukayo, Weide, Mbarika and Kim, 2012). As in other MIS courses, students taking this course learn about knowledge about data communications and networking through lectures, case studies, textbooks, and assignments (Abenza, Olivo and Latorre, 2008; Bobbitt, Inks, Kemp and Mayo,

2000; Nadkarni, 2003). However, researchers have argued that these conventional teaching approaches alone are not sufficient to improve students' enjoyment of the subject (Mbarika et al., 2010; Bagarukayo et al., 2012; Zoller and Pushkin, 2007). MIS students often find it difficult to comprehend and communicate technical concepts about data communications and networking in class (Bolino, Turnley and Bloodgood, 2002) and to relate the theoretical knowledge to practical situations. Traditional education methods are also not good at helping students to stay focused on the course content (Nadolski et al., 2008). These disadvantages combine to hinder students from gaining a good learning experience, which in turn makes it hard for them to concentrate and enjoy the course.

One possible solution to complement the insufficient of conventional teaching is to introduce serious games in Data Communications and Networking Management courses. Serious games are used for purposes other than pure entertainment (Liu, Li and Santhanam, 2013; Michael and Chen, 2005; Wasko, Teigland, Leidner and Jarvenpaa, 2011); they are designed to help students develop a better understanding of theoretical concepts and retain related professional knowledge (Ebner and Holzinger, 2007; Erhel and Jamet, 2013). The virtual world simulated in a serious game provides students with multiple opportunities to understand how the concepts and techniques work in a practical setting (Amory, Naicker, Vincent and Adams, 1999; Rienzo and Han, 2011). Serious games have been shown to improve students' motivation and concentration (Liu et al., 2013; Hainey et al., 2013). An additional benefit is that serious games can help players enjoy the learning experience while playing games (Roussou, 2004). But, research on the impact of serious games on improvement in learning experience for a Data Communications and Network Management course is sparse. Hence, we propose the following research question:

How do features of serious games influence students' concentration and enjoyment of the games, which in turn improve their perceived HOCS in a Data Communications and Networking Management course?

In the next section, we develop the research model and associated hypotheses guiding this research. Next, we describe the research methodology and present the results of our analysis. Finally, we discuss the findings of this study and their implications for management scholars and practitioners as well as the limitations and suggestions for future research.

THEORETICAL BACKGROUND AND HYPOTHESES DEVELOPMENT

Serious games are designed to simulate the type of practical problems typically encountered in actual workplaces to enable players to acquire and practice the cognitive skills needed to solve diverse problems in real-world situations (Connolly, Boyle, MacArthur, Hainey and Boyle, 2012). According to the literature review conducted by Boyle et al. (2016) and Connolly et al. (2012), much research has shown that serious games are helpful to improve learning outcomes such as knowledge acquisition, behavior changes, soft skills acquisition and performance improvement. Romero et al. (2015) state that serious games help develop students' skills of critical thinking and problem solving, which are two important components of HOCS. Games help increase students' learning effectiveness through providing a good learning experience (Kiili, 2005; Webster, Trevino and Ryan, 1994); an enjoyable learning experience has been shown to increase students' engagement in serious games and eventually improve their learning performance (Shernoff, Csikszentmihalyi, Shneider and Shernoff, 2003). Serious games provide students with an interactive simulation experience (Vogel et al., 2006; Wouters, Van Nimwegen, Van Oostendorp and Van Der Spek, 2013). Aspects of the learning experience such as

concentration and enjoyment can help improve students' cognitive skills; if students cannot focus on the serious games or feel no interest in them, their cognitive skills are unlikely to improve. Our survey of the literature found that features such as challenge, perceived ease of use and perceived usefulness improve students' enjoyment of learning (Roussou, 2004) and their concentration on the serious games. Hence, we hypothesize that three features of serious games, challenge, perceived ease of use and perceived usefulness, influence students' learning experience by improving their concentration and enjoyment, which in turn enhances their learning outcome (in this case, perceived improvement of HOCS). Figure 1 shows our conceptual model, which will be explained in the next section.

-----Insert Figure 1-----

Hypotheses

Five hypotheses have been developed based on the relationships portrayed in the research model.

Impact of Challenge on Learning Experience

A challenge typically consists of a series of assigned tasks, usually with increasing levels of difficulty (Malone and Lepper, 1987; Pavlas et al., 2009). In playing serious games, challenges are especially important since they ensure educational purposes are fulfilled within the game-playing process (Johnson, Vilhjálmsón and Marsella, 2005). Students develop their skills by applying knowledge to solve problems and receiving feedback on their performance (Charsky, 2010; Gee, 2003), with the challenges providing intrinsic motivation for students to engage in learning activities (Lepper and Henderlong, 2000). Challenges have a positive effect on people's concentration. Perceived levels of challenges in tasks may be positively related to perceived levels of concentration (Ghani, Supnick and Rooney, 1991; Koufaris, 2002; Kiili, 2005). This indicates that when they perceive an appropriate level of challenge, students pay more attention to the tasks and concentrate on solving the problems involved. Hence, we propose the following hypothesis:

Hypothesis 1a: *Perceived challenge in serious games is positively related to perceived concentration.*

Researchers have empirically confirmed the positive relationship between challenge and perceived enjoyment. Past literature shows that perceived levels of challenge in a task positively affect team members' perceived enjoyment (Ghani et al., 1991) and learners experience higher levels of playfulness with increased levels of challenge (Webster and Ho, 1997). People feel joyful when engaging in activities with challenges such as games because psychological needs such as competence and autonomy are satisfied while playing the games (Deci and Ryan, 2000). Hence, we propose the hypothesis:

Hypothesis 1b: *Perceived challenge in serious games is positively related to perceived enjoyment.*

Impact of Ease of Use and Usefulness on Learning Experience

The Technology Acceptance Model (TAM) is widely used by information system researchers to explain users' acceptance and usage of new technologies (Davis, 1989; Venkatesh, 2000). In TAM, two major concepts, perceived ease of use and perceived usefulness, are believed to have

a significant impact on users' attitudes and intentions to use a particular technology (Bhattacharjee and Premkumar, 2004). Serious games can be considered as a new technology to be adopted and used in teaching so that it is necessary and essential for us to explore the effects of perceived ease of use and perceived usefulness on students' learning results. We therefore included these two concepts because they both represent features of serious games. Perceived ease of use reflects the level of difficulty experienced when playing a serious game and perceived usefulness reflects the value of a serious game to the students playing it.

Perceived ease of use refers to the degree of effort users exert when using a technology (Teo, Lim and Lai, 1999). It is a significant predictor of perceived enjoyment for those using websites (Van Schaik and Ling, 2011), the Internet (Teo et al., 1999) and hedonic systems (Lowry, Gaskin, Twyman, Hammer and Roberts, 2012; Van der Heijden, 2004). If a system is easy to use, it removes barriers to using technology and reduces the difficulty of accessing core functions, resulting in users improve concentration and enjoyment (Van Schaik and Ling, 2011). Hence, we propose the following hypotheses:

***Hypothesis 2a:** Perceived ease of use in serious games is positively related to perceived concentration.*

***Hypothesis 2b:** Perceived ease of use in serious games is positively related to perceived enjoyment.*

Perceived usefulness refers to users' anticipation regarding how much a technology will help them increase their job performance (Teo et al., 1999). Perceived usefulness positively affects users' attitudes towards a particular technology and may improve their concentration and enjoyment (Hsu and Lu, 2004; Lu, Zhou and Wang, 2009; Saadé and Bahli, 2005). Hence, we propose the following hypotheses:

***Hypothesis 3a:** Perceived usefulness in serious games is positively related to perceived concentration.*

***Hypothesis 3b:** Perceived usefulness in serious games is positively related to perceived enjoyment.*

Impact on Perceived Higher-order Cognitive Skills

HOCS capabilities include critical thinking, problem solving and decision making, which are all important learning outcomes (Zoller, 1993; Mbarika, Sankar and Raju, 2003). In contrast to lower order cognitive skills (LOCS), which include skills such as memorizing and reciting general knowledge acquired in class (Zoller, 1993), HOCS enable students to apply the knowledge acquired in learning to solve problems (Bond, Wang, Sankar, Raju and Le, 2014).

Impact of Concentration on Perceived HOCS

Concentration can be defined as “exclusive, focused attention on an experience and places the user in a separate state of mind—a state in which the user is not conscious of anything outside the experience” (Abenza et al., 2008, p. 600). Players experiencing periods of focused concentration while playing a serious game will have a positive attitude towards the game's value leading to improved HOCS (Sánchez, Canto, Farias and Dormido, 2011; Wang, Rajan, Sankar and Raju, 2014); the more students concentrate on serious games, the more they may perceive that they have improved their HOCS. Hence, we propose the following hypothesis:

***H4:** Perceived concentration in serious games is positively related to perceived HOCS.*

Impact of Enjoyment on Perceived HOCS

Enjoyment is “the extent to which the activity of using a specific system is perceived to be enjoyable in its own right, aside from any performance consequences resulting from system use” (Venkatesh, 2000, p. 351). An enjoyable experience enhances students’ intrinsic motivation to play serious games resulting in improving HOCS ((Liu et al., 2013; Fu, Su and Yu, 2009). Hence, we propose the following hypothesis:

H5: *Perceived enjoyment in serious games is positively related to perceived HOCS.*

RESEARCH METHODOLOGY

An empirical study was designed to test the hypotheses presented above. We developed a 26-question survey. Participants were asked to complete the survey and also to submit a 4-page group report after playing serious games. We then applied structural equation modeling (SEM) to analyze the survey data and combined this with the students’ reports to develop our findings.

Participants

A total of fifty-three undergraduate students enrolled in two sessions of a Data Communications and Networking Management course, each lasting one semester, in the business school of a large southeastern university participated in the experiment. One month after the semester started, all participants were required to play at least one of the serious games about telecommunication provided on the CISCO website (https://learningnetwork.cisco.com/community/learning_center/games). This website hosts eight free games about telecommunication technologies. Students were asked to write a report about their perceptions of playing serious games and also to complete an online questionnaire as a project assignment. The reason we chose this time point is that it enabled students to gain an overall understanding of telecommunication technologies during the one-month study period. The results allowed us to determine whether playing serious games did indeed help the students better understand and apply the data communications and networking skills they learned in class to solve the problems presented by the game.

Features of Serious Games

We provide an example of the three features of a serious game (challenge, perceived ease of use and perceived usefulness) using the Cisco Binary Game. A screenshot from this game is shown as Figure 2. The main objective of this game is to help players learn and practice using the binary number system. Various conversion formats are used: for example, players may convert a binary number into a decimal number, while in others they must arrange “0” and “1” correctly to make the binary number equal a given decimal number. The number of conversions increases and every correct solution removes one conversion. Players are challenged to complete each conversion quickly, as incomplete conversions fill the game screen. Scores and the difficulty level of the game are displayed on the right hand side of the screen, so players are aware that the game is becoming harder, with larger numbers and more conversions in each level. Students in this study could perceive different degrees of challenge in this game even if they are playing at the same difficulty level. They can also evaluate whether the binary game is easy to understand and manipulate and whether this game is helpful to their studies. Hence, three

features of serious games, namely the (perceived level of) challenge and the perceived ease of use and usefulness, are present in the Cisco Binary Game and it is thus appropriate for this test of the proposed hypotheses. In a similar manner, the other games chosen for this study included these three features appropriately.

-----Insert Figure 2-----

Construct Operationalization

There are six constructs in our study: challenge, perceived ease of use, perceived usefulness, concentration, enjoyment and HOCS (Figure 1). All constructs were measured using 5-point Likert scales (ranging from 1 = “Strongly disagree” to 5 = “Strongly agree”). The scale items are listed in Appendix A.

Challenge was measured by a three-item reflective scale adapted from Koufaris (2002) and Novak et al. (1998). It reflects the students’ perceptions of the extent of the challenge in the serious games.

Perceived Ease of Use was measured by a six-item reflective scale that combined items from Agarwal and Karahanna (2000) and Venkatesh and Morris (2000). It was operationalized as the extent to which students felt it was easy to operate the serious games. One of the items was dropped before further analysis since its loading coefficient was inadequate.

Perceived Usefulness refers to the perceived extent of usefulness of serious games. Adapted from prior literature (Agarwal and Karahanna, 2000; Bhattacharjee and Premkumar, 2004; Venkatesh and Morris, 2000), *Perceived Usefulness* was measured with a four-item reflective scale.

Concentration was operationalized as the extent to which students were focused when playing the serious games. It was measured by a four-item reflective scale adopted from Koufaris (2002) and Guo and Klein (2009).

Following Koufaris (2002), *Enjoyment* was termed as the perceived extent to which the students enjoyed playing serious games. It was measured by a four-item reflective scale.

HOCS referred to students’ perceptions of their abilities related to identifying, integrating, interrelating, evaluating and solving problems after playing serious games about data communications and networking. A five-item scale was derived from Hingorani, Sankar and Kramer (1998) and Bond et al. (2014) to measure HOCS. One item was dropped before further analysis since it did not load well.

Control Variable

When researching the effects on HOCS, many researchers have used gender as an important predictive variable (Aydin and Yilmaz, 2010; Bagarukayo et al., 2012). We therefore introduced gender as a control variable to investigate whether this did indeed have an effect on the perceived improvement of HOCS.

DATA ANALYSIS RESULT

The Partial Least Square (PLS) method was selected for the data analysis given the sample size of 53. Unlike other covariance-based SEM methods, PLS is based on variance and does not

restrict sample size (Fornell and Bookstein, 1982). SmartPLS software was used to test the construct validity and reliability, and to assess the research model consisting of six latent variables with 26 items, as well as a control variable. A bootstrapping procedure was applied to test the statistical significance of the parameter estimates in SmartPLS.

Construct Validities and Reliabilities

Convergent validity was confirmed, as indicated by the Confirmatory Factor Analysis (CFA) results shown in Appendix A. All the factor loading coefficients are larger than 0.7 at a significance level of 0.001, indicating that all the retained items are significantly loaded onto their representative constructs. The positive square roots of AVE are shown in the major diagonal of the correlation matrix in Table 1 and the Average Variance Extracted (AVE) values for each construct are all larger than 0.5, indicating that at least 50 percent of the variances in the items are explained by the latent construct. Hence, all the results in Table 1 satisfy the criteria proposed by Fornell and Larcker (1981), confirming the convergent validity of the scale items used in this study.

-----Insert Table 1-----

Discriminant validity among the constructs was also verified, as shown in Table 1. Given that the value of the positive square root of AVE for each construct should exceed its correlation coefficients with other constructs (Fornell and Larcker, 1981), the values for the square root of AVE listed in the principal diagonal in the correlation matrix should be larger than all other correlation coefficients that are listed in the same row and also in the same column. As this requirement is satisfied, discriminant validity is confirmed.

The reliability of the measurements was tested using Composite Reliability (CR) coefficients, which are also listed in Table 1. The composite reliability coefficients of all the latent constructs exceed the required minimum of 0.7, indicating sufficient reliability.

Hypothesis Testing

The results from the PLS analysis are shown in Figure 3. Significant paths are shown in solid lines with a star above the path coefficients; R square values are displayed immediately under the names of the constructs.

-----Insert Figure 3-----

All the hypothesized paths from individual serious game features to the construct of concentration (H1a, H2a and H3a) are significant at a level of 0.05, as shown in Table 2. Challenge, perceived ease of use and perceived usefulness jointly explained 58.3% of the variance for concentration. Challenge is positively related to perceived concentration in playing serious games about telecommunication technologies, thus supporting H1a ($\beta = 0.317$ and $p\text{-value} < 0.05$). Perceived ease of use is another significantly positive predictor of students' perceived concentration in serious games, supporting H2a ($\beta = 0.352$ and $p\text{-value} < 0.05$). Hypothesis 3a, positing that perceived usefulness of serious games positively influences concentration, is also supported ($\beta = 0.296$ and $p\text{-value} < 0.05$).

-----Insert Table 2-----

Interestingly, not all the hypothesized paths from individual serious game features to the construct of enjoyment (H1b, H2b and H3b) are significant, as shown in Table 3. Taken together, these three features explain 49.9% of the variance for perceived enjoyment, but challenge is not significantly related to enjoyment ($\beta = 0.098$ and $p\text{-value} > 0.05$), suggesting that H1b is not supported. This means that level of difficulty does not affect students' perceived enjoyment of serious games. The effect of perceived ease of use on concentration is not significant at a significance level of 0.05 ($\beta = 0.246$ and $p\text{-value} = 0.071 > 0.05$), thus failing to support Hypothesis 2b. However, the perceived usefulness of serious games is positively related to students' enjoyment ($\beta = 0.515$ and $p\text{-value} < 0.05$), offering strong support for H3b.

-----Insert Table 3-----

The hypothesized paths from learning experience (H4 and H5) to the construct of HOCS are both positive and significant, meaning that both concentration and enjoyment have positive influences on the perceived improvement in HOCS gained by playing serious games (Table 4). When combined with the control variable, gender, they explain 38.3% of the variance in HOCS. Hypothesis 4, which posits that concentration when playing serious games is positively related to a perceived improvement in HOCS, is supported ($\beta = 0.314$ and $p\text{-value} < 0.05$). Enjoyment is also proved to positively influence HOCS, providing support for H5 ($\beta = 0.365$ and $p\text{-value} < 0.05$). However, there is no significant effect of the control variable, gender, on students' perceived enhancement of HOCS. This indicates that both female and male students use serious games to improve their HOCS in the same way.

-----Insert Table 4-----

In summary, all the hypotheses except H1b and H2b are supported by these empirical results. The coefficients of the variables in these supported hypotheses are statistically significant at a level of 0.05. The three dependent variables in our model (concentration, enjoyment and HOCS) are all well explained by the model, with a minimum R^2 value of 38.3%.

FINDINGS AND IMPLICATIONS

The empirical results lead to four main findings:

1. The perceived degree of challenge is positively related to students' concentration when playing serious games, but is not significantly related to the students' enjoyment of the games.
2. Perceived ease of use has a significantly positive effect on students' concentration when playing serious games, but its effect on the enjoyment of the games is not significant.
3. The perceived usefulness of serious games is significantly and positively related to students' concentration and enjoyment when playing the games.
4. Students' concentration and enjoyment when playing serious games significantly and positively influences their perceived improvement in their HOCS.

These findings have valuable implications for future research and practice.

Findings

The empirical results indicate that the perceived level of challenge is positively related to the perceived level of concentration when playing serious games. Students will focus more intently on the games if they feel the games are challenging to finish, so a perceived higher level of challenge can motivate students to devote their full attention to solving the problems in serious games. This finding confirms that challenge is a strong predictor of concentration in the student learning process, which is consistent with prior research (Ghani et al., 1991; Kiili, 2005). In contrast, if students feel the games are too easy for them, they may become bored while playing and become easily distracted. This finding is consistent with our analysis of the students' learning reports. The computer games about telecommunication technologies that we offered to the study participants have different degrees of difficulty. Some students stated in their reports that the games they played on the CISCO website were challenging and they had to concentrate on figuring out the solutions in order to continue the games. However, other students considered that the games they played were not challenging enough and hence they lost their concentration when playing.

However, our results show that challenge is not significantly related to students' perceived enjoyment in the learning process (Figure 3). This means that regardless of whether the games are hard or easy for the students, this may not actually affect their perceptions of the enjoyment in playing serious games. This could be because students can enjoy playing serious games with different levels of challenge. If students feel one game is very difficult to play, they may be motivated to participate in the game and enjoy the process of trying many solutions, but if another game is really easy for them, they may also enjoy it since other factors, such as competitions among players, could make it fun. Most of the students who played the binary game, for example, considered the game itself as not hard but still enjoyed playing it since they could compete with other players. Three of these students even reported that they had become slightly addicted to this game and kept playing repeatedly because they wanted to gain the highest score. As one explained:

"It is also very fun and addicting because it makes you strive to have the highest score and beat your competitors. You can see how you rank in score compared to everyone else who has played the game online."

The perceived ease of use was also significantly and positively related to students' concentration in playing serious games. This indicates that if students feel it is easy to use the serious games, they will focus their efforts on searching for solutions to the problems in the games rather than becoming distracted by the need to overcome operational problems. When it is easier and faster for students to become involved in the games, they simply have a more enjoyable experience. Although the results show that the effect of perceived ease of use on students' enjoyment in serious games is not significant at a level of 0.05, it is significant and positive at a level of 0.1 ($p\text{-value}=0.071$), as shown in Table 3. This suggests that students do to some degree enjoy serious games more if they find them easy to use. This is consistent with previous research that argues that perceived ease of use has a positive and significant effect on people's attitudes and enjoyment (Bhattacharjee and Premkumar, 2004; Teo et al., 1999; Van Schaik and Ling, 2011). The converse is also true: students are annoyed and lose concentration if they find it hard to operate the functions in the games. This ruins their overall learning experience of playing serious games and gives them a very bad impression. For example, one student who has played the binary game stated that:

“While this game helped me learn binary math, the gameplay interface was somewhat dull and boring and did not add anything to the game experience. Furthermore, after completing a few levels I found like my biggest challenge was being able to physically click the buttons fast enough to keep the screen from filling up. The interface was not very user-friendly and this detracted from the overall gameplay experience.”

According to our results, the effect of perceived ease of use on concentration experience is stronger than the effects of challenge and perceived usefulness, with a larger standard path coefficient (0.352) as shown in Figure 3 and Table 2. This means that perceived ease of use is a strong predictor and it will be significantly easier for students to concentrate on serious games if they do not have to overcome operational obstacles. It also indicates that students can concentrate on the games mainly because they feel the games are easy to use.

The third finding of this study is that the perceived usefulness of serious games has a strong positive effect on students' concentration and enjoyment. This indicates that students will concentrate more and enjoy the process of playing serious games if they consider such games to be useful for their study of data communications and networking topics. This finding confirms prior studies that highlighted the positive effect of perceived usefulness on users' positive attitudes towards and intention to use new technologies (Hsu and Lu, 2004; Lu et al., 2009; Saadé and Bahli, 2005). Students who believe these serious games help them to learn telecommunication technologies are more strongly motivated to play well, and at the same time are more likely to have a positive attitude towards serious games. This is also helpful in increasing their feeling of enjoyment. Other students, who consider serious games to be just an assignment and an additional study burden, are more likely to have a negative attitude and to play the game mindlessly, failing to concentrate on the games or feel any joy in the process. Most students in our study used words such as “useful”, “beneficial” and “educational” when describing games that they played and also mentioned that such useful games are “fun”, suggesting that they really enjoyed playing the games. In addition, based on our empirical results, perceived usefulness has a larger standardized path coefficient (0.515) than that for perceived ease of use (0.246), as shown in Figure 3 and Table 3, indicating that the perceived usefulness has a stronger positive effect on perceived enjoyment. This further confirms that perceived usefulness produces a positive attitude and is likely the main reason why students feel serious games are enjoyable.

Finally, both concentration and enjoyment learning experience were positively related to students' perceived improvement of higher order cognitive skills (HOCS). A good learning experience, represented here by concentration and enjoyment, is an antecedent for improved learning outcomes in areas such as HOCS. This finding is consistent with results from other studies, which have shown not only that concentration is positively related to learning outcomes (Pardos, Baker, San Pedro, Gowda and Gowda, 2013), but that students who experience enjoyment during studying gain better learning outcomes (Gomez, Wu and Passerini, 2010). This suggests that whether it is in the context of traditional learning (reading books, listening to lectures and so on) or in the context of serious games, a beneficial learning experience, manifested by concentration and enjoyment, is consistently important and can enhance students' learning outcomes, especially HOCS. Further evidence for this is provided by our analysis of the students' reports. Those who stated that they had experienced both concentration and enjoyment when playing serious games felt that they had improved their understanding of the knowledge and technological skills related to data communications and networking, but those students who did not find the experience engaged their attention or did not enjoy the games thought that they

had barely learnt anything from the games and it was a waste of time to play them. Since the standardized path coefficient of the construct of concentration (0.314) is very close to that of enjoyment (0.365), as shown in Figure 3 and Table 4, we conclude that concentration and enjoyment equally affect students' perceived improvement in HOCS in serious telecommunication games.

Implications

The findings of this study offer several implications for researchers, educators, companies, and serious games design companies.

For researchers, this article empirically confirms the positive effects of serious game features (challenge, perceived ease of use and perceived usefulness) on students' learning experience (concentration and enjoyment), as well as the perceived positive effect on students' HOCS. These results provide researchers with insights into ways to improve students' HOCS in the context of serious games. Given that game research in information systems is still in its infancy (Agarwal and Karahanna, 2000; Liu et al., 2013), this study significantly enhances the literature related to the use of serious games in education not only in IS but also in other academic areas. In addition, the research framework proposed here, which includes serious games features, learning experience and learning outcomes, can be used in the future research in IS and may also be applied to other academic areas. Finally, our introduction of perceived ease of use and perceived usefulness from the TAM model as two game features proved to be both necessary and useful, thus providing other researchers with evidence of the utility of introducing TAM model variables when conducting research into learning outcomes from serious games.

For educators, our findings indicate that serious games may help students improve their critical thinking, decision-making and problem-solving skills in a Data Communications and Networking Management course. It is both feasible and proper to introduce serious games in courses such as Data Communications and Networking Management or other technical related areas to support traditional teaching approaches and add fun to the students' learning process and thus improve their learning outcomes. Students have also expressed their support for introducing serious games into courses; one student commented that the game helped them to develop a better understanding of the course knowledge:

"These games are far more effective than the traditional lecture which we are all exposed to where the lecturer is throwing out highly technical and specific terms which are not fully understood (because of) the vast educational difference among the listeners."

Students who played binary game also noted that this game helped them improve HOCS, further supporting our empirical results.

However, when talking about what kinds of students should use serious games in courses, students had different opinions. Some thought that it would be more beneficial for younger students, while others suggested that serious games were indeed suitable for college students. This unsurprising finding is likely due to the different knowledge and skill levels of the participants and indicates the importance of choosing games that pose an appropriate level of challenge for the students taking the course in order to gain positive learning outcomes.

High-tech companies are competing with each other to hire and retain competent employees who are knowledgeable about their technologies and are adept at using these to create new products/ services. Many of them do not have sufficient knowledge about underlying technologies. This study shows that serious games may motivate them to master these

technologies and improve their HOCS; this may be a superior methodology compared to them attending week-long workshops on these technologies.

For serious game design companies, it is necessary to emphasize the importance of challenge in serious games. Companies should identify their target students first and then design games that incorporate special knowledge and skills with proper levels of challenge to maximize students' learning outcomes. Games should incorporate up-to-date content and knowledge and utilize friendly and easy-to-use interfaces to maximize the students' learning experience.

LIMITATIONS AND FUTURE WORK

Several limitations in this study need to be recognized. The most obvious is the limited sample size of the current study due to the relatively small class sizes in the Data Communications and Networking Management course in the participating business school. Although we are confident that this does not affect the results of our research since PLS does not have a minimum requirement for sample size. A larger sample would increase the validity of the results. We therefore expect that future research may validate our model by experimenting with a larger sample size. Second, we measured HOCS using student perceptions and future work needs to develop more objective measures of HOCS. Third, only the three features of serious games were included in this study. Further research could expand on this by examining the impact of adding other features such as goal clarity, competition and feedback mechanisms to the research model to build a more comprehensive understanding of the utility of serious games.

CONCLUSIONS

This study investigated how serious games help improve the HOCS of undergraduate students enrolled in a Data Communications and Networking Management course. Based on the model developed for this study, our findings confirmed that challenge, perceived ease of use and perceived usefulness all have positive effects on students' concentration and enjoyment when playing serious games and this, in turn, has a positive effect on students' HOCS. These empirical results were analyzed in conjunction with student reports on their experience of playing serious games, supporting the effectiveness of using serious games in a Data Communications and Networking Management course. Our findings should encourage educators to incorporate serious games into data communications and networking and other similar technology-based courses to improve students' HOCS.

In addition, these results should motivate game companies to design and produce more serious games for learners. With the support of both educators and game companies, we believe students can significantly improve their HOCS in these important areas using serious games, which will be beneficial to their future career. This study contributes to research into the use of serious games in the classroom and provides valuable insights to guide future research.

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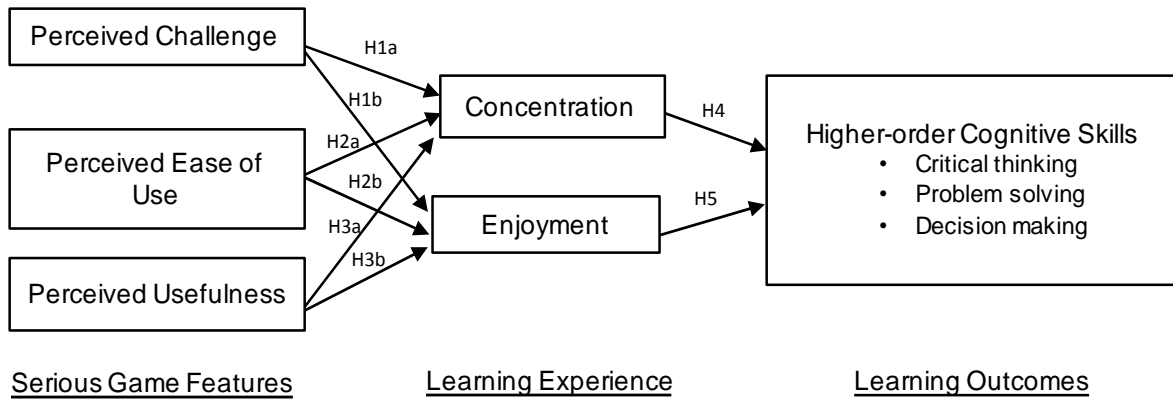


Figure 1. Conceptual Model

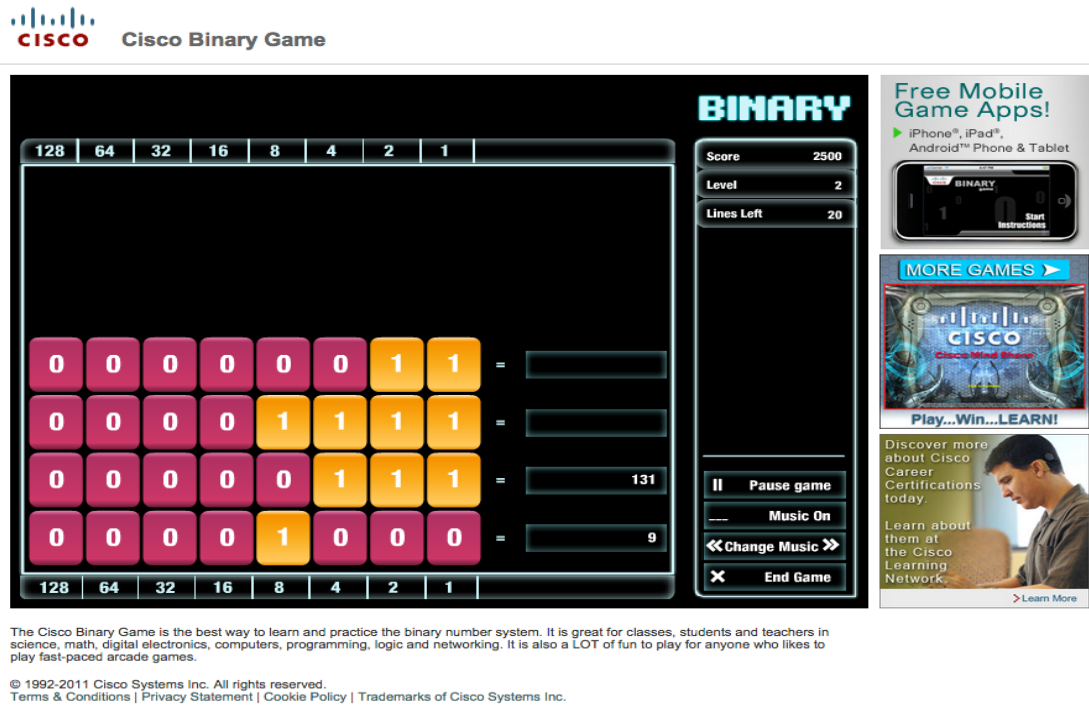


Figure 2. Cisco Binary Game Screenshot

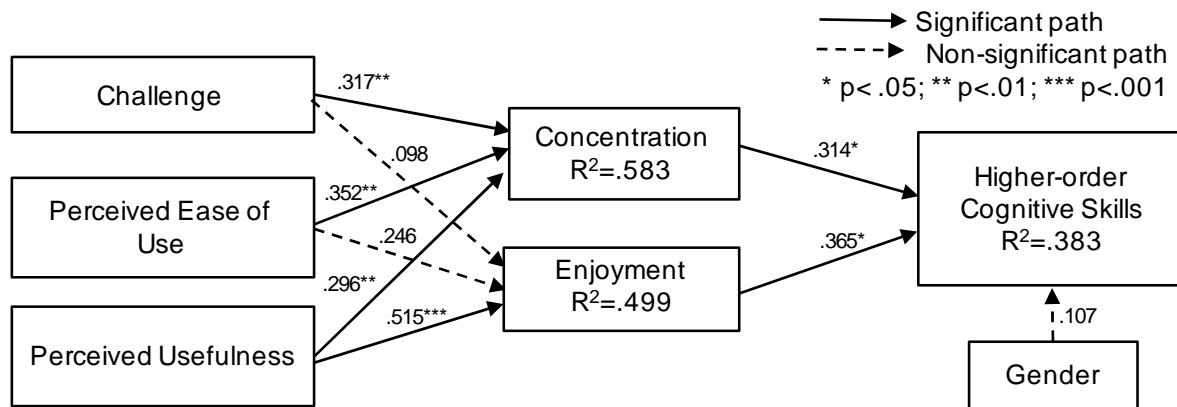


Figure 3. PLS Analysis of Results

Table 1

Correlations of Latent Variables

| Construct | Mean | S.D. | Alpha | Composite Reliability | 1 | 2 | 3 | 4 | 5 | 6 |
|-----------------------|------|------|-------|-----------------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Challenge | 3.82 | .72 | .919 | .85 | .813 | | | | | |
| Perceived Ease of Use | 3.62 | .72 | .779 | .91 | .588 | .840 | | | | |
| Perceived Usefulness | 3.81 | .73 | .848 | .94 | .444 | .604 | .898 | | | |
| Concentration | 3.46 | .78 | .892 | .86 | .510 | .536 | .555 | .777 | | |
| Enjoyment | 3.40 | .87 | .858 | .93 | .507 | .589 | .657 | .641 | .870 | |
| HOCS | 3.86 | .64 | .734 | .91 | .344 | .573 | .474 | .373 | .376 | .811 |

Note: N= 53; AVEs on diagonal

Table 2

Concentration as the Dependent Variable

| Hypothesis | Factor | β | t-value | p-value | R² |
|------------|-----------------------|---------|---------|---------|-------|
| H1a | Challenge | 0.317 | 2.989 | 0.003 | 58.3% |
| H2a | Perceived Ease of Use | 0.352 | 3.417 | 0.001 | |
| H3a | Perceived Usefulness | 0.296 | 2.897 | 0.004 | |

Table 3

Enjoyment as the Dependent Variable

| Hypothesis | Factor | β | t-value | p-value | R² |
|------------|-----------------------|---------|---------|---------|-------|
| H1b | Challenge | 0.098 | 0.991 | 0.322 | 49.9% |
| H2b | Perceived Ease of Use | 0.246 | 1.811 | 0.071 | |
| H3b | Perceived Usefulness | 0.515 | 4.300 | <0.001 | |

Table 4

HOCS as the Dependent Variable

| Hypothesis | Factor | β | <i>t</i> -value | <i>p</i> -value | <i>R</i> ² |
|------------------|---------------|---------|-----------------|-----------------|-----------------------|
| H4 | Concentration | 0.314 | 2.213 | 0.027 | 38.3% |
| H5 | Enjoyment | 0.365 | 2.008 | 0.045 | |
| Control variable | Gender | 0.107 | 1.058 | 0.290 | |

Appendix A: Scale Items and EFA Factor Loadings**Table A1**

Scale Items and Factor Loadings

| Constructs and Items | Factor |
|---|---------------|
| Challenges | |
| 1. The games challenged me to perform to the best of my ability. | .837 |
| 2. The games provided a good test of my skills | .826 |
| 3. The games stretched my capabilities to the limits | .776 |
| Perceived Ease of Use | |
| 1. Learning to use the games was easy for me. | .803 |
| 2. I found the games flexible for interactions between tasks and activities. | (Deleted) |
| 3. I found it easy to get the games to do what I wanted to do. | .889 |
| 4. It was easy for me to become skillful at using the games. | .848 |
| 5. I found the games easy to use at work. | .768 |
| 6. My interaction with the games at work was clear and understandable. | .737 |
| Perceived Usefulness | |
| 1. Using the games as instructional materials was useful. | .878 |
| 2. Using the games as instructional materials increased my productivity. | .865 |
| 3. Using the games as instructional materials enhanced my effectiveness | .884 |
| 4. Using the games as instructional materials made it easier to do my work. | .854 |
| Concentration | |
| 1. I was absorbed intensely during gaming time. | .841 |
| 2. My attention was focused on the games. | .776 |
| 3. I concentrated fully on the games. | .884 |
| 4. I was deeply engrossed during gaming time. | .853 |
| Enjoyment | |
| 1. During the game I found it interesting. | .930 |
| 2. During the game I found it enjoyable | .931 |
| 3. During the game I found it exciting. | .903 |
| 4. During the game I found it fun. | .823 |
| HOCS | |
| When using the games to learn Data Communications and networking knowledge::I learn | |
| 1. I learned how to inter-relate important topics and ideas. | (Deleted) |
| 2. I learned how to identify various alternatives/solutions to a problem. | .833 |
| 3. I learned how to improve my problem solving skills. | .701 |
| 4. I learned how to sort relevant from irrelevant facts | .769 |